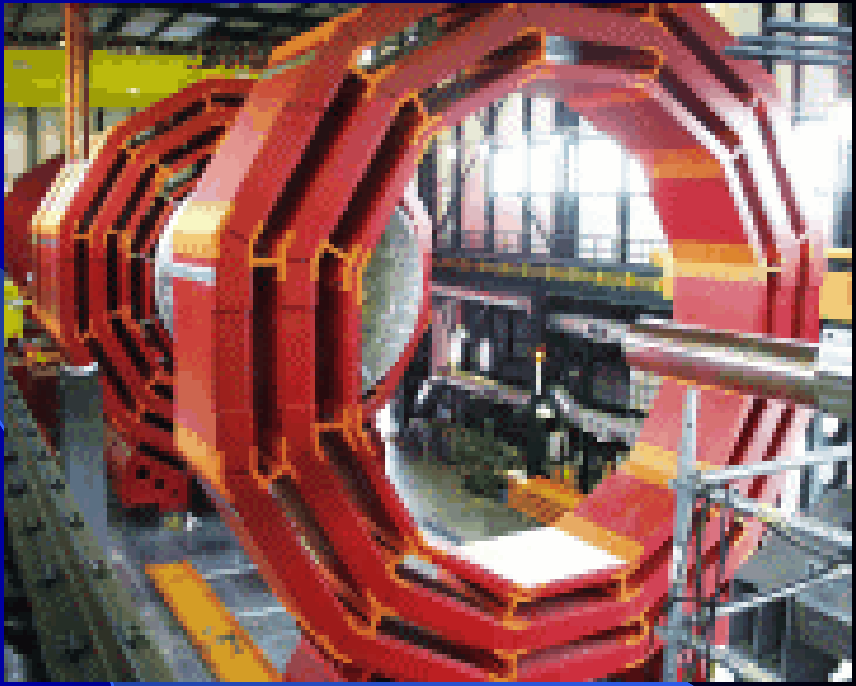
Technical Challenges in Constructing the CMS Experiment



Jefferson Lab
Newport News, VA (USA)
February 6, 2003

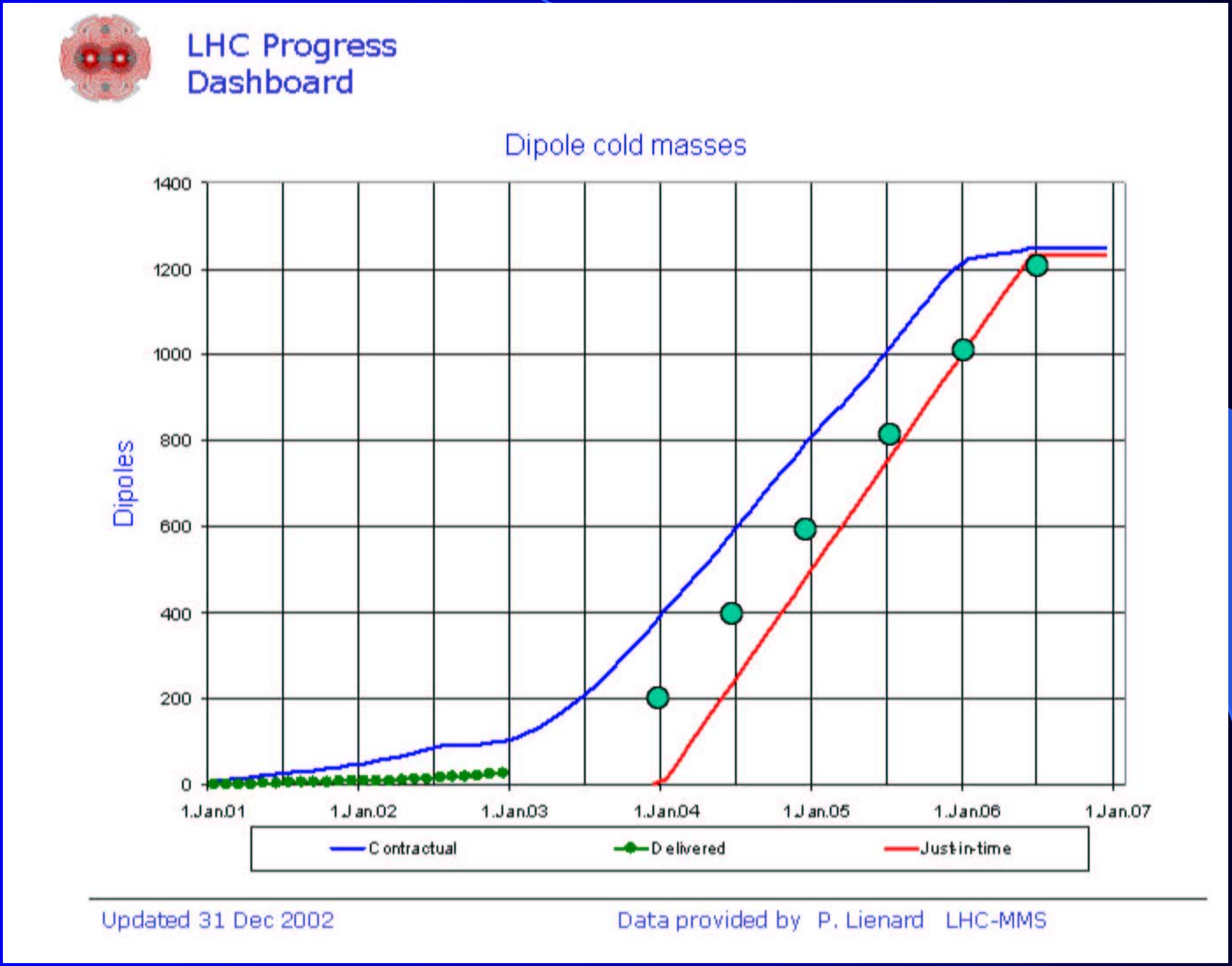
Hans Rykaczewski
CERN and ETH Zurich
CMS ECAL and Magnet Resources Manager

CERN and the Large Hadron Collider

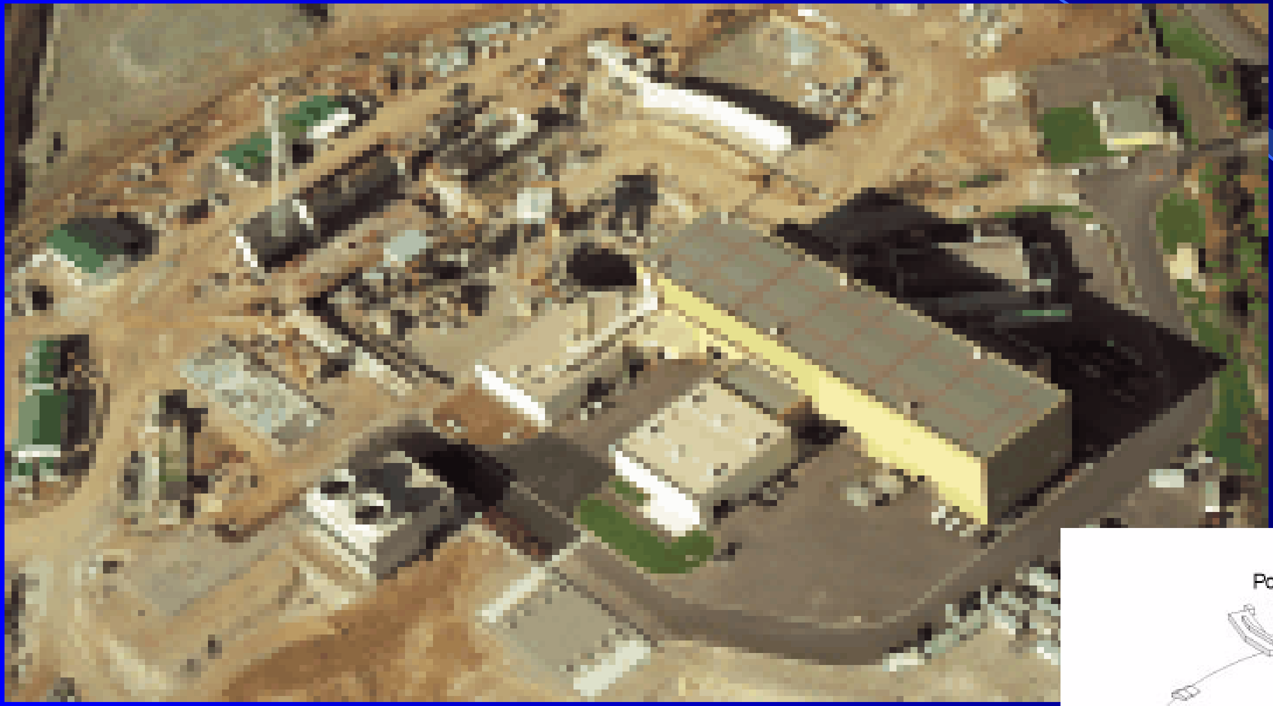
LHC Schedule

end 1998	work started on experimental sites
end 2000	removal of LEP
September 2002	surface buildings on schedule, all excavations finished
April 2003	caverns ready for ATLAS
July 2004	caverns ready for CMS
2002 – 2006	production and installation of LHC magnets
December 2006	machine closed and cooled
early 2007	machine commissioning (one beam)
April 2007	first collisions (pilot run)
July – November 2007	physics run – collect 3-5 fb^{-1} at 10^{33} cm^{-2} s^{-1}
March 2008	heavy ions run

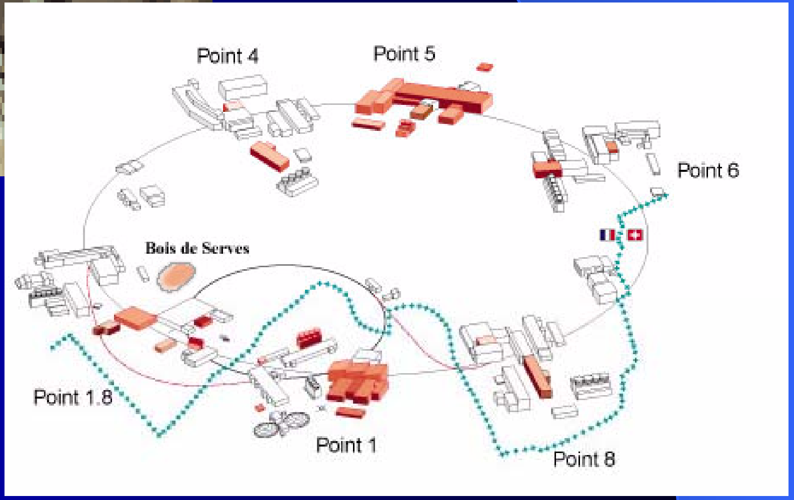
LHC Dipole Production Schedule



The LHC and the CMS Experiment

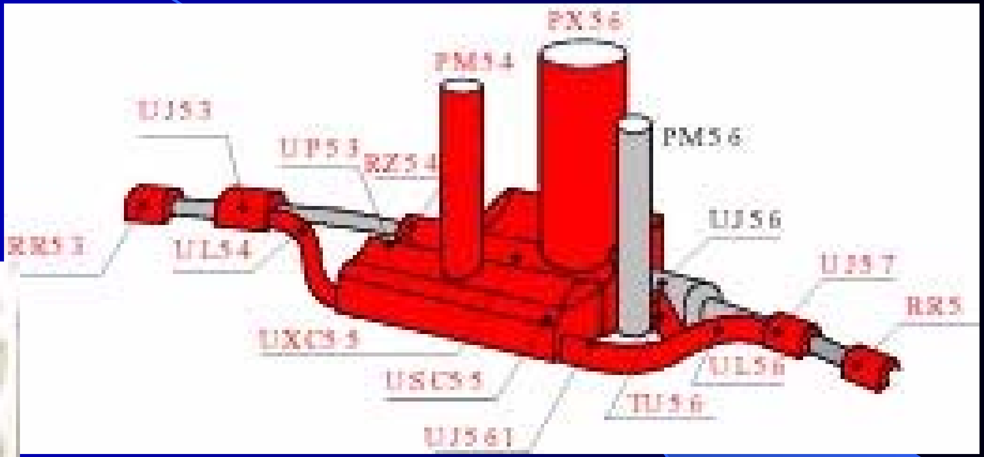


CMS will be Located at Point 5 of the LHC in Cessy



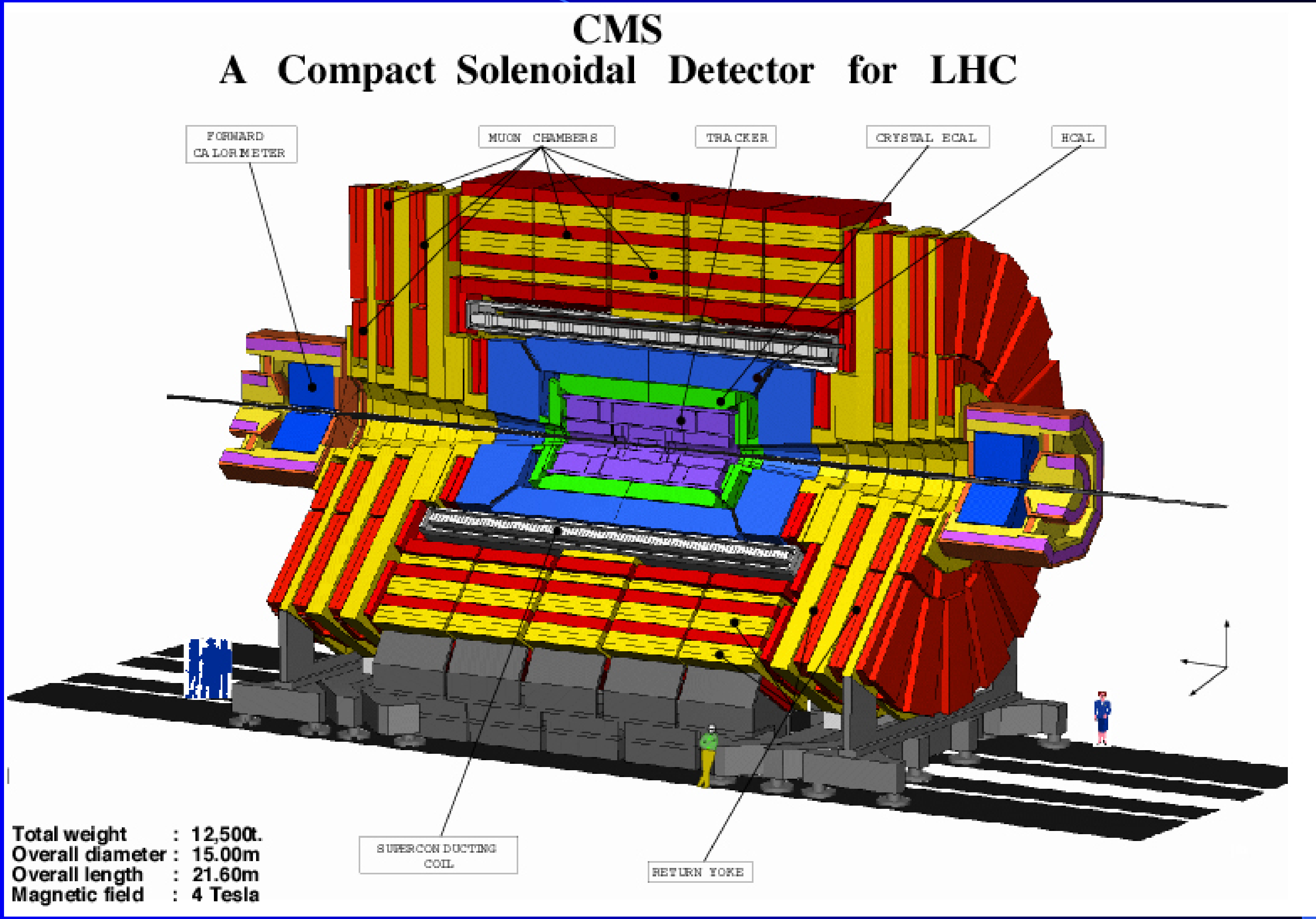
CMS Experimental Area

- The CMS Experiment will be located at a depth of 90 m below surface.

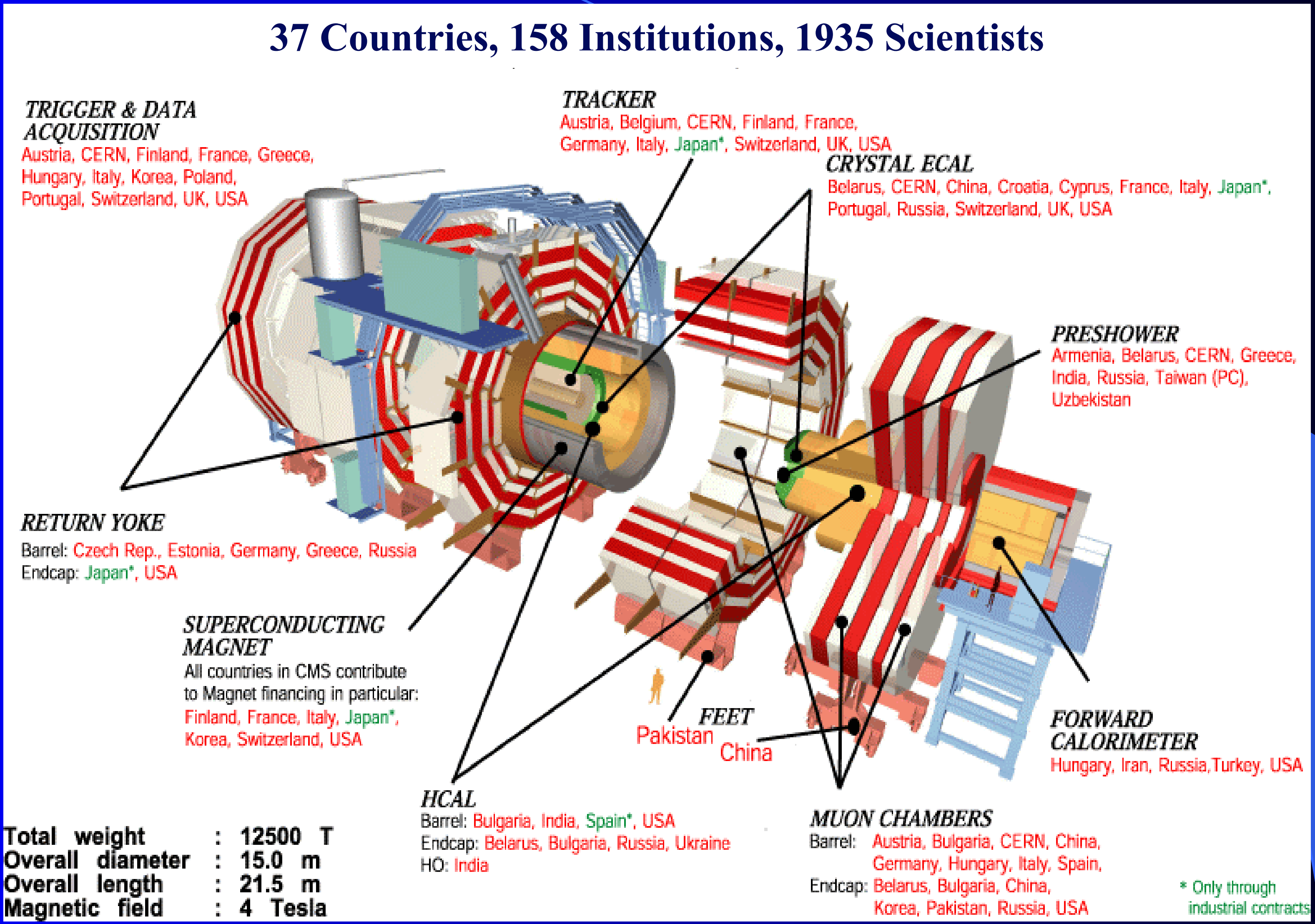


- A large experimental cavern, a service cavern and two shafts have been excavated.

The CMS Experiment



CMS is a Truly Global Collaboration



The CMS Magnet

The CMS Magnet design is very simple:

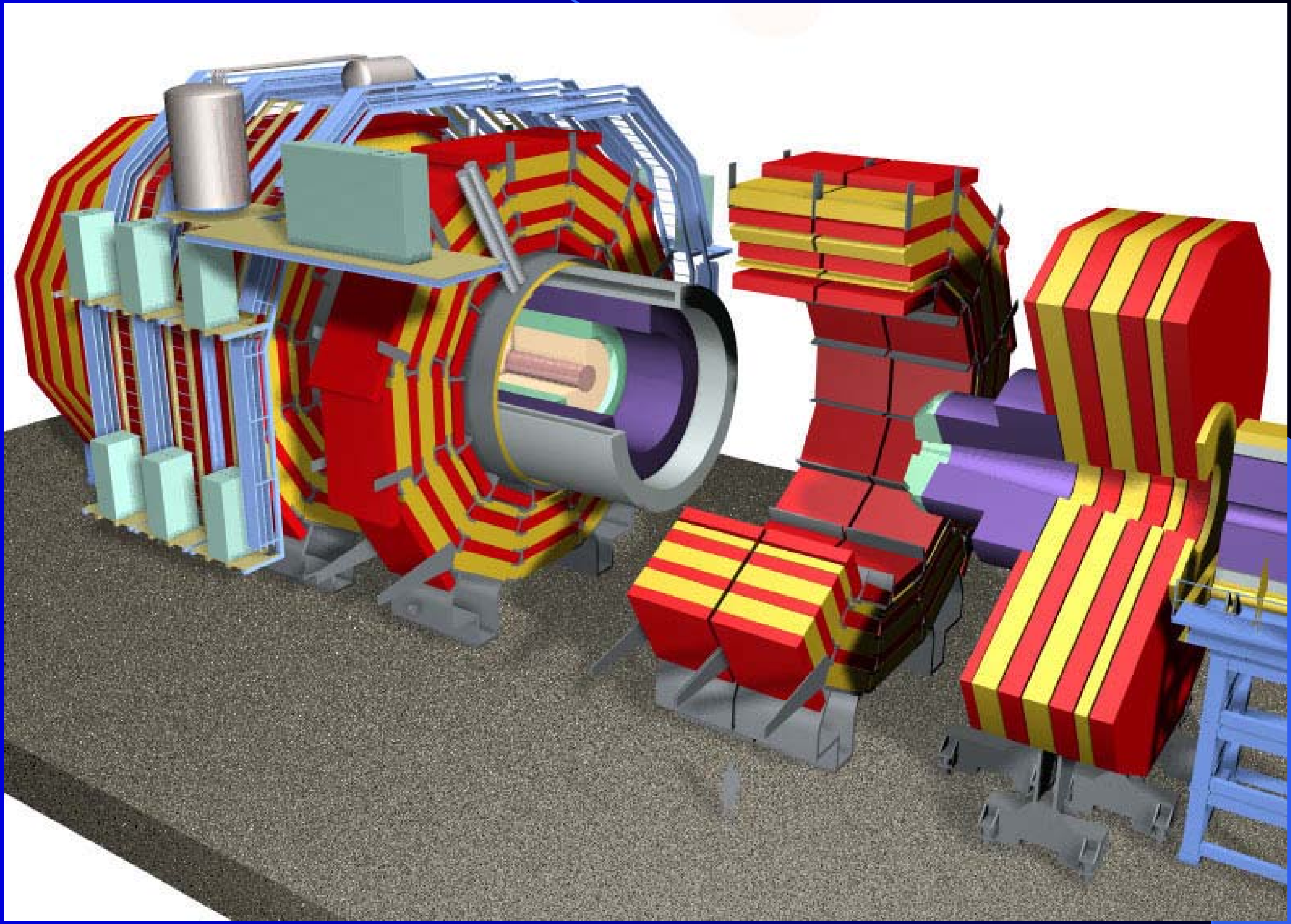
Like any electromagnet it consists of
- a piece of iron and
- a coil.

Construction and management is organized accordingly.

The Piece of Iron

Barrel:
5 Rings +
Vacuum Tank

Endcaps:
3 Disks
on each side



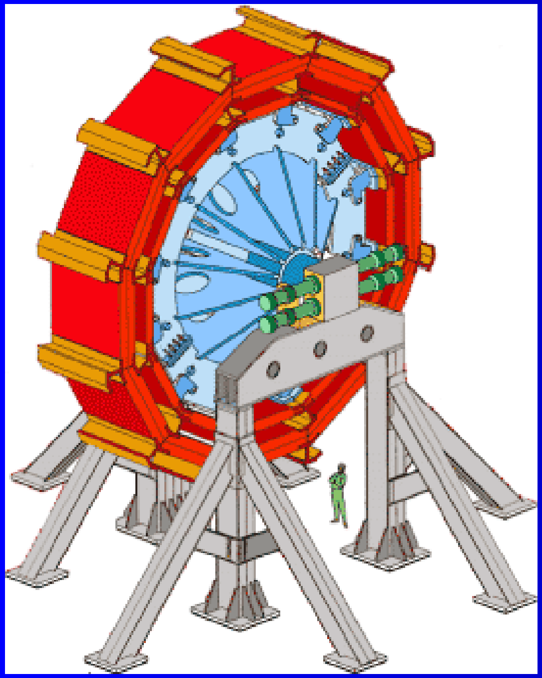
Main Parameters of the CMS Magnet Return Yoke

• Diameter	14 m
• Length	13 m
• Thickness of Iron Layers (Barrel)	300, 630 & 630 mm
• Mass of Iron (Barrel)	6000 tons
• Thickness of Disks (Endcaps)	600, 600 & 250 mm
• Mass of Iron (Both Endcaps)	4000 tons
• Total Mass of Iron	10000 tons

Main Parameters of the CMS Superconducting Coil

• Magnetic Length	12.5 m
• Free Bore Diameter	6 m
• Radial Thickness of Cold Mass	312 mm
• Weight of Cold Mass	220 tons
• Central Magnetic Field	4 Tesla
• Maximum Induction on Conductor	4.6 Tesla
• Total Ampere · Turns	42.5 MA · Turns
• Nominal Current	20 kA
• Inductance	14 H
• Stored Energy	2.7 GJ

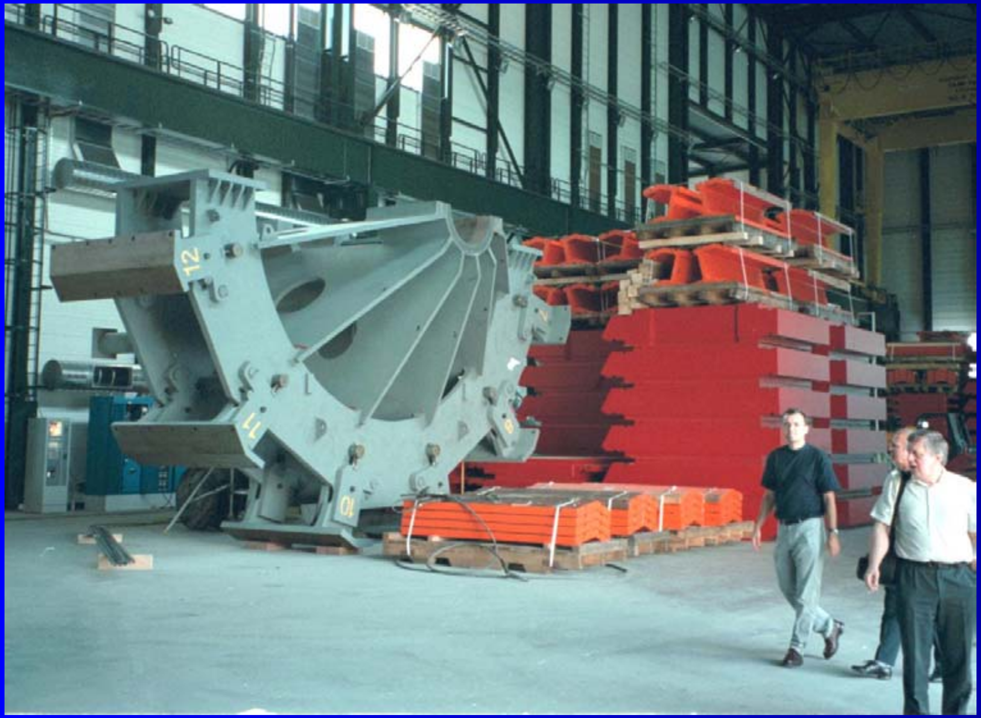
Central Ring of the Barrel Yoke



Technical Design Report May 1997

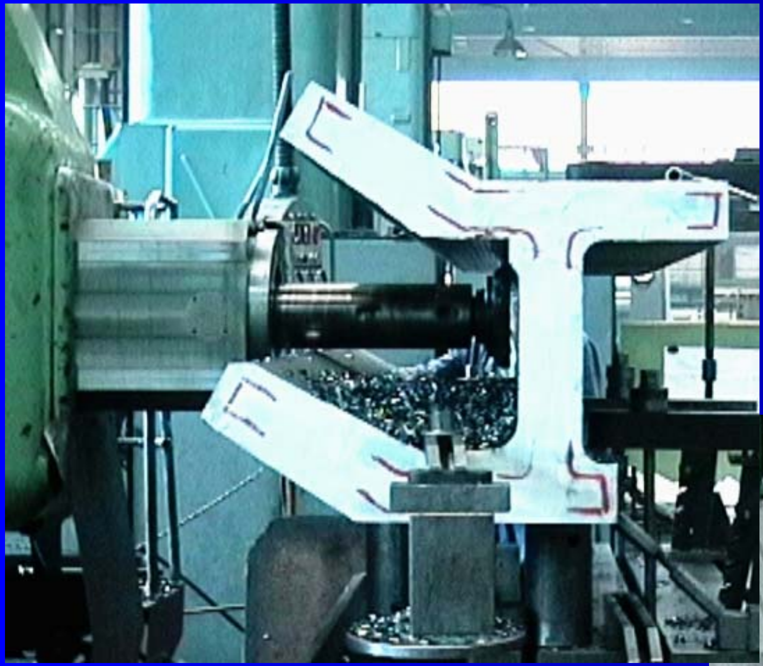
Reality - SX5 Beginning 2001

Material for the Barrel Yoke



Thick Iron Blocks Forged by Izhora (Russia)

Brackets and Corner Pieces by ZDAS (Czech Rep.)



Weight of one bracket is about 2 tons.

Iron Blocks are Fixed by Tie Bars

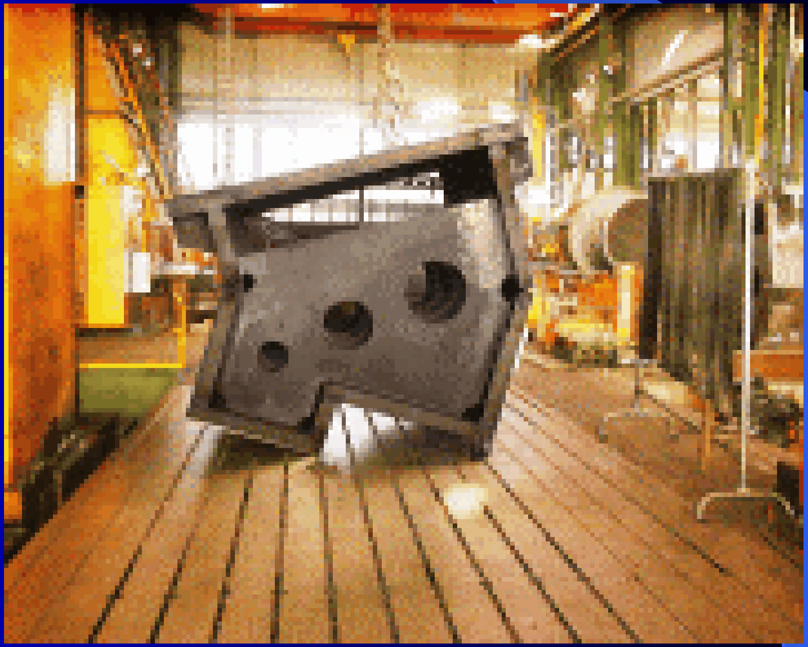
Five Rings of the CMS Magnet Barrel

Hans Rykaczewski
CERN & ETH Zurich

Production of Barrel Support Feet

Support feet of central ring by DWE in Germany.

Support feet for the four outer rings were made by SES in Pakistan.



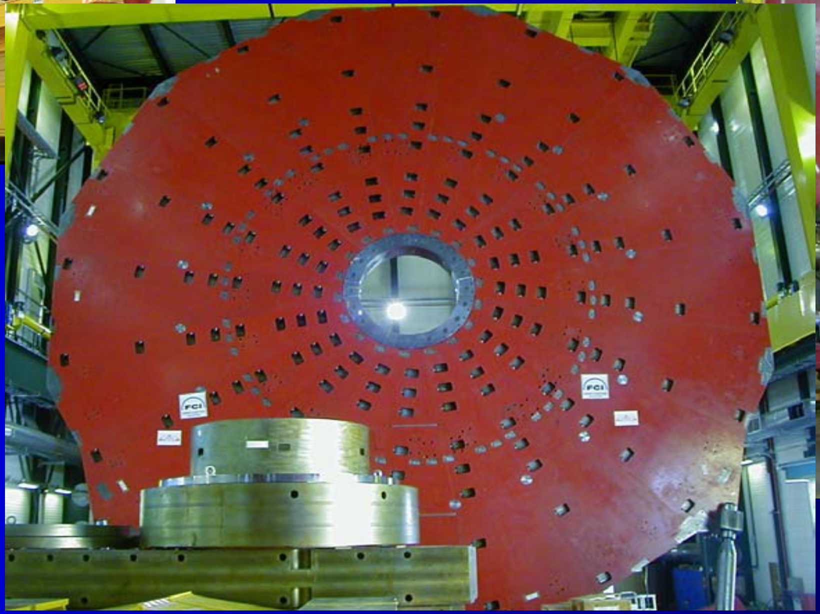
Support Feet and Air Pads of Barrel Rings

Endcap Support Carts Produced by Hudong (China)

Endcaps Manufactured by Kawasaki (Japan)

- Six Disks
- Each Disk has 20 Sectors
- Fixed by Superbolts
- Survey by Photogrammetry

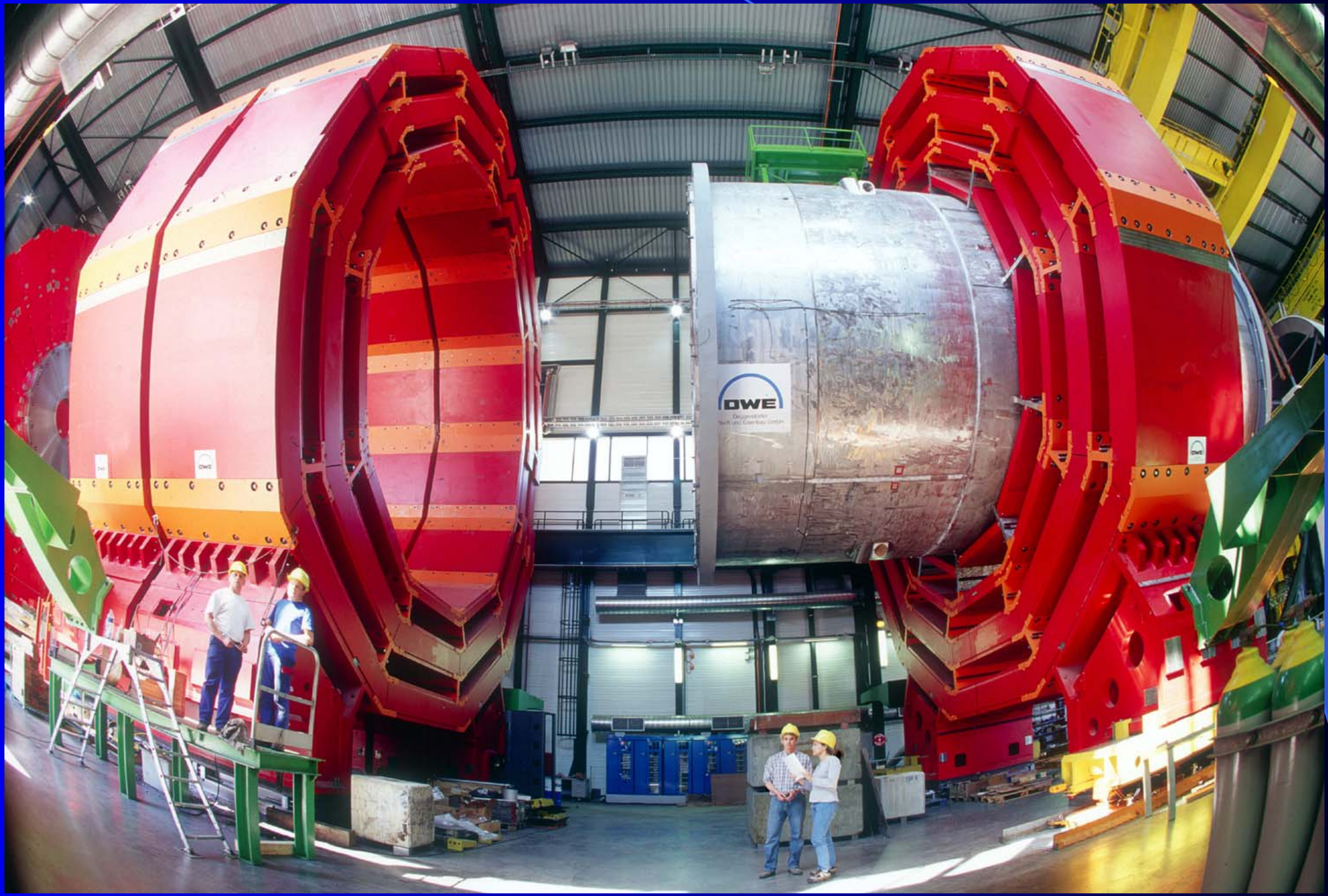
Assembly of Endcap Disks at CERN



Outer Shell of Vacuum Tank

- Final Welding at CERN-P5
- Two Half-Shells
  => One Sector
- Three Sectors
  => Outer Shell

Central Ring, Outer Shell of Vactank and 2 Outer Rings



Inner Shell of Vacuum Tank

Integrated Rails to Support Inner Detectors

Largest Single Piece of CMS Inner Shell of Vacuum Tank

Weight: 120 tons
Diameter: 5.5 meters
Length: 12 meters

Produced at FCI
in Lons Le Saunier.

About 120 km away
from CERN, across
the Jura Mountains.

Transported to CERN in May 2001 – one week special transport

Transport of Inner Shell of Vacuum Tank

Transport of Inner Shell to P5

Arrival at experimental area

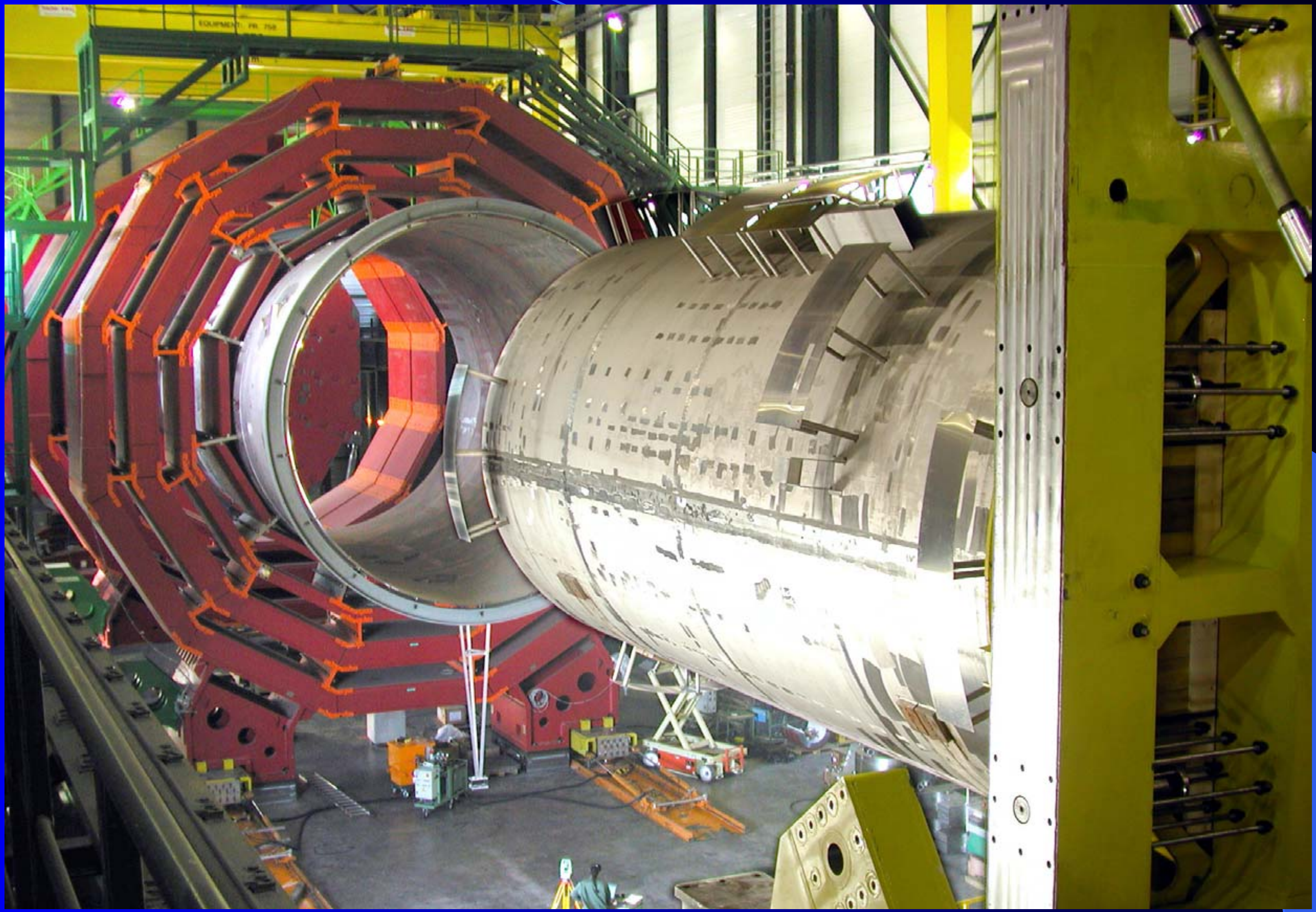
… and it even fits into the hall

Swiveling Platform Produced by Doosan (Korea)

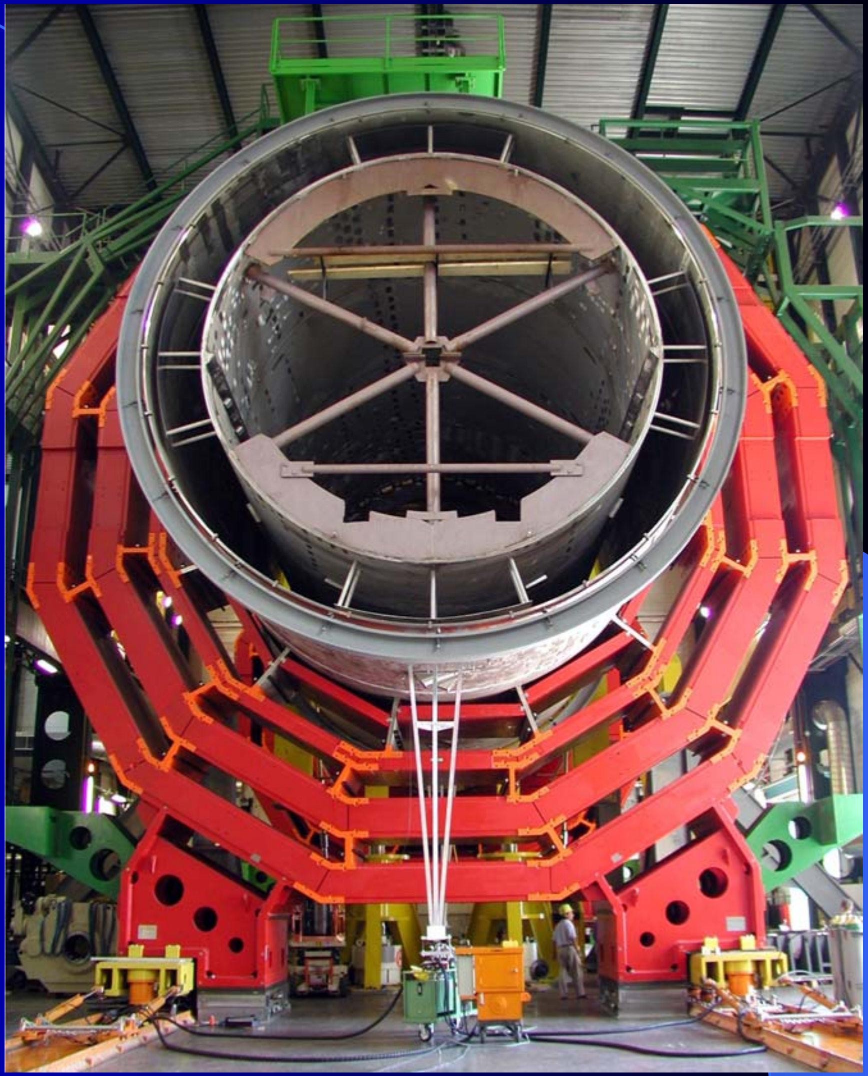
Inner Shell of Vacuum Tank on Swiveling Platform

Rotating the Inner Shell of the Vacuum Tank

Test Insertion of the Inner Shell

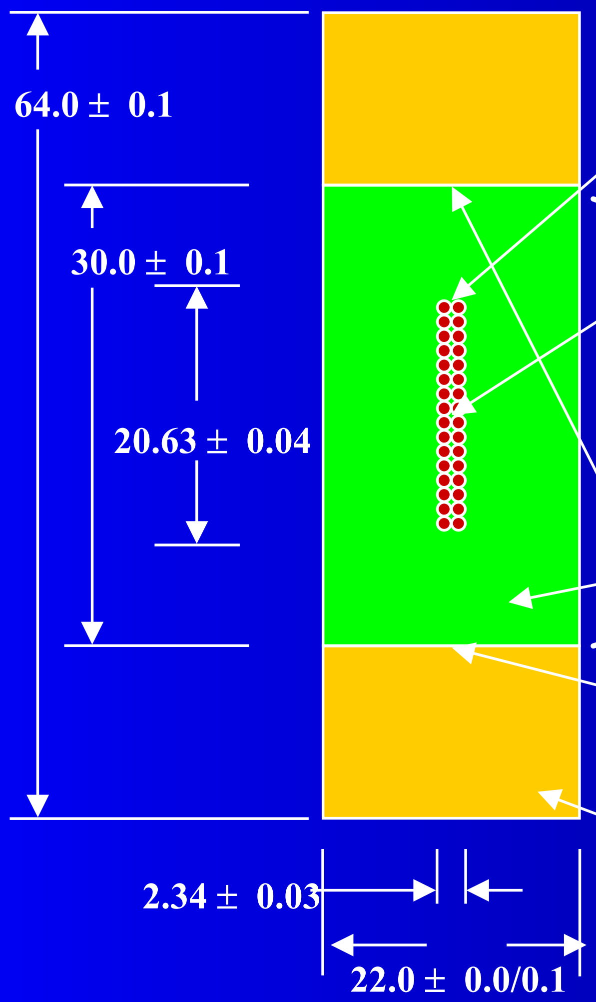


… and also this fits.



Titanium Alloy Tie Rods from Lutch (Russia)

Components of the CMS Conductor



32 Superconducting Strands ø: 1.28 mm
2000 km from Outokumpu (Finland)

Cabling of Strands into Rutherford Cable
55 km cable from Kabelwerke Brugg (Switzerland)

Co-Extrusion
Manufactured by Nexans (Switzerland)

99.998% Pure Aluminum
120 tons from Sumitomo Chemical (Japan)

Electron Beam Welding of Alloy for Reinforcement
Manufactured by Techmeta (France)

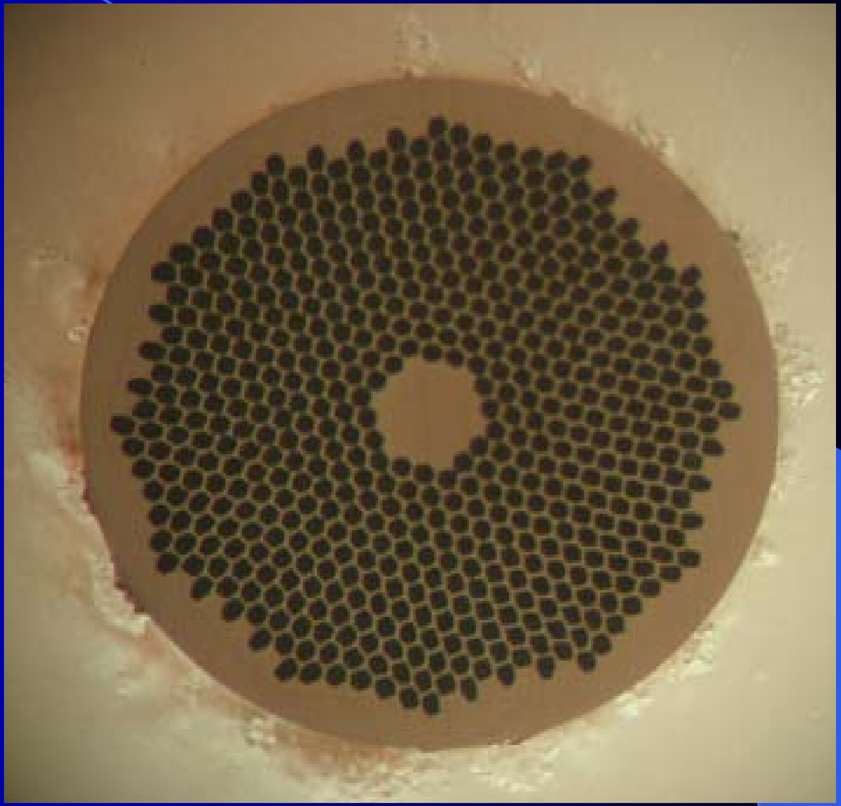
Aluminum Alloy for Reinforcement
120 tons form Alcan (Switzerland)

Superconducting Strands by Outokumpu (Finland)

$J_c = 3140\ A/mm^2$ @ 5T

$I_c = 1925$ A @ 5T

600 Nb - Ti filaments in a copper matrix



Cu/Sc = 1.3

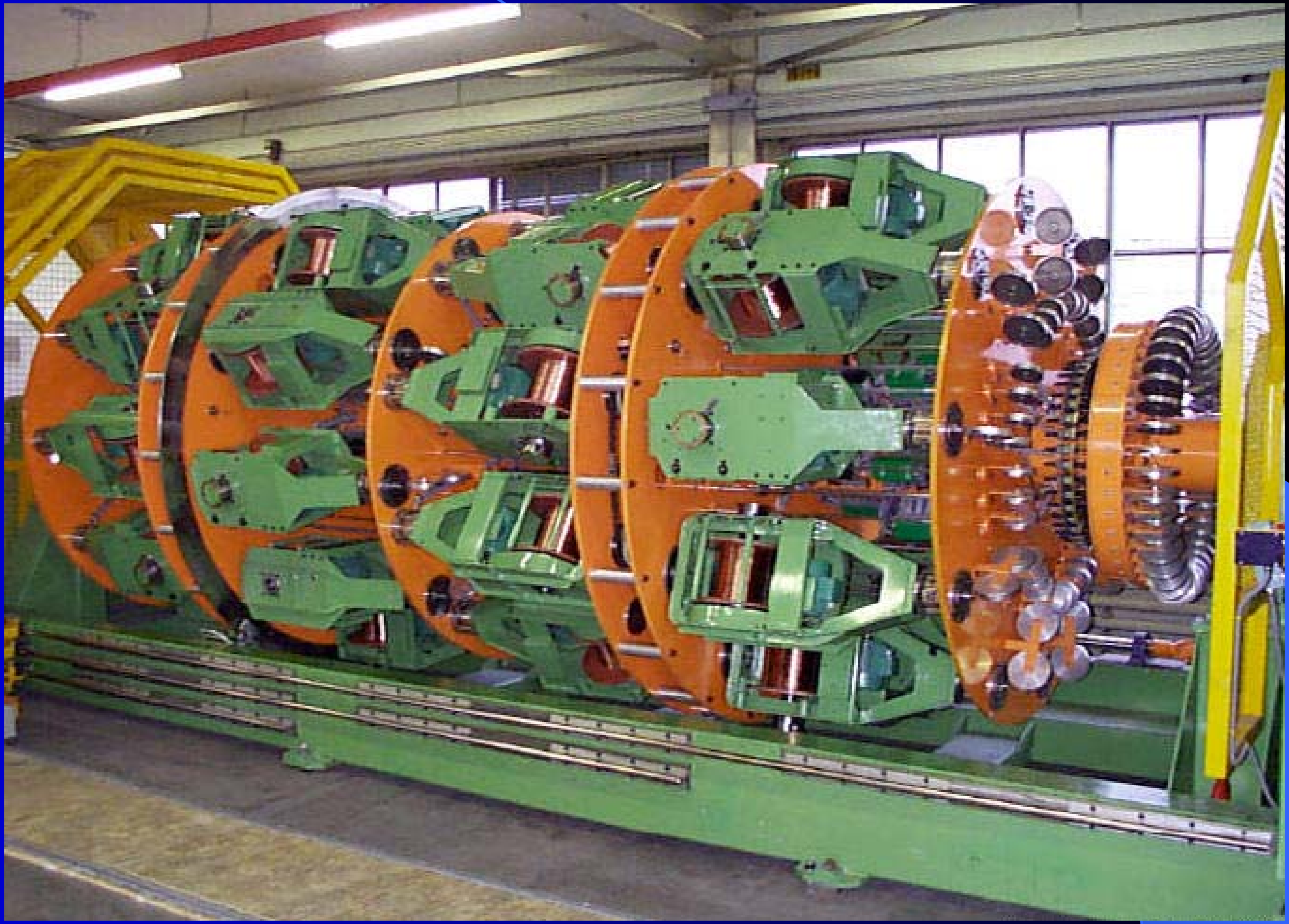
Ø strand = 1.24 mm

Cabling at Kabelwerke Brugg (Switzerland)

Cabling stopped in summer 2002 due to a technical breakdown.

Cabling operation began again in October.

All cabling done!



Co-extrusion of the Insert at Nexans (Switzerland)

Superconducting cable manufactured by

Kabelwerke Brugg (Switzerland)

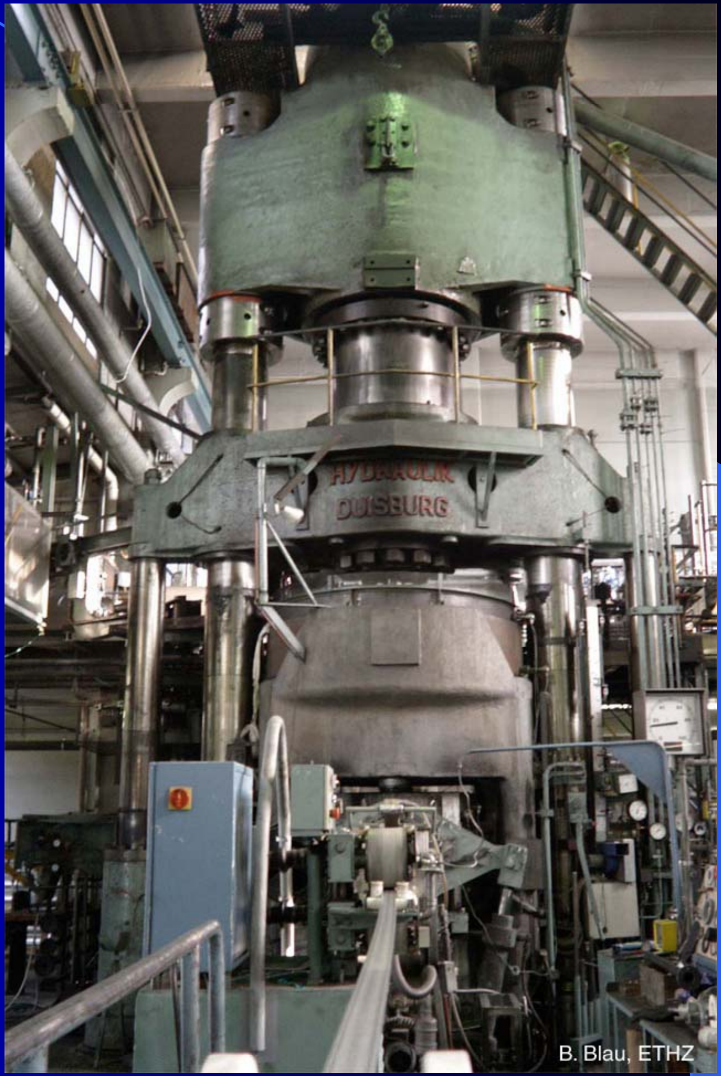
and

high purity (99.998%) aluminium produced by

Sumitomo Chemical (Japan)

is continuously co-extruded by

Nexans (Cortaillod, Switzerland)



Reinforcement of Insert at Techmeta (France)

The insert co-extruded

by Nexans (Switzerland)

is reinforced with

two stripes of aluminium alloy

produced by

Alcan (Switzerland)

by using electron beam welding at

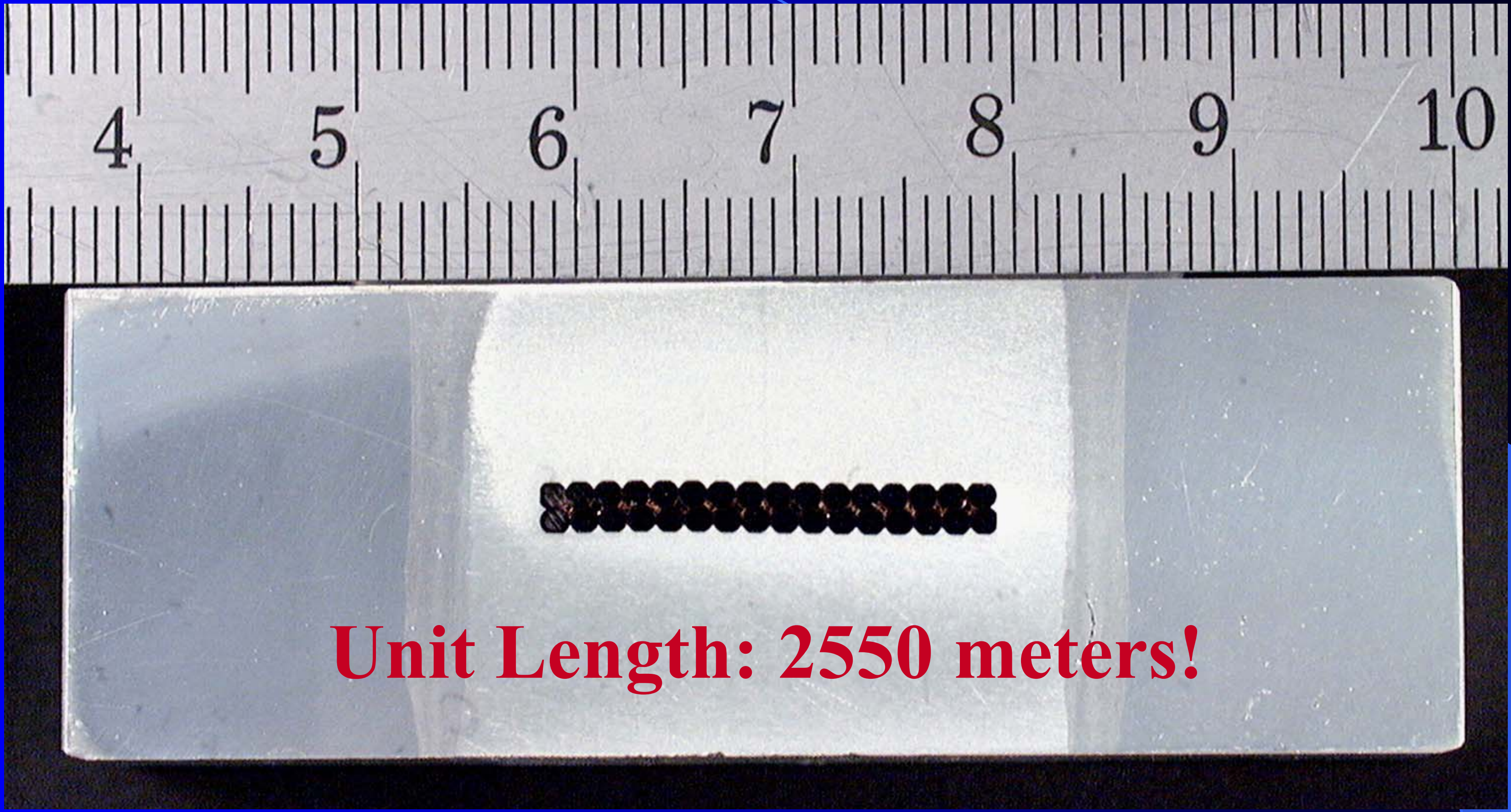
Techmeta (France).

Electron Beam Welding of Reinforcement

Cleaning of Reinforced Conductor

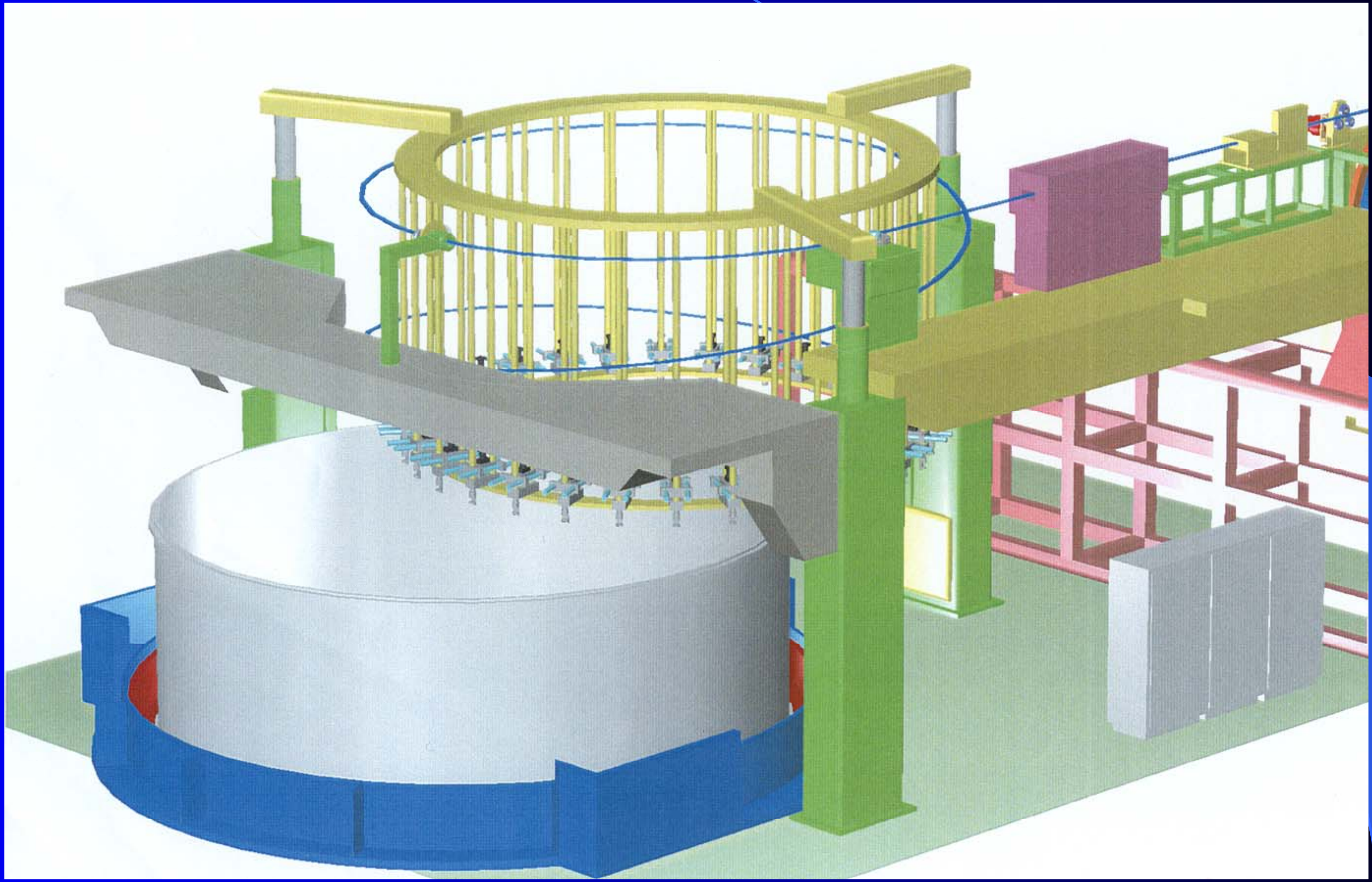
Ultrasonic Quality Control of Conductor

Finished Superconducting Conductor

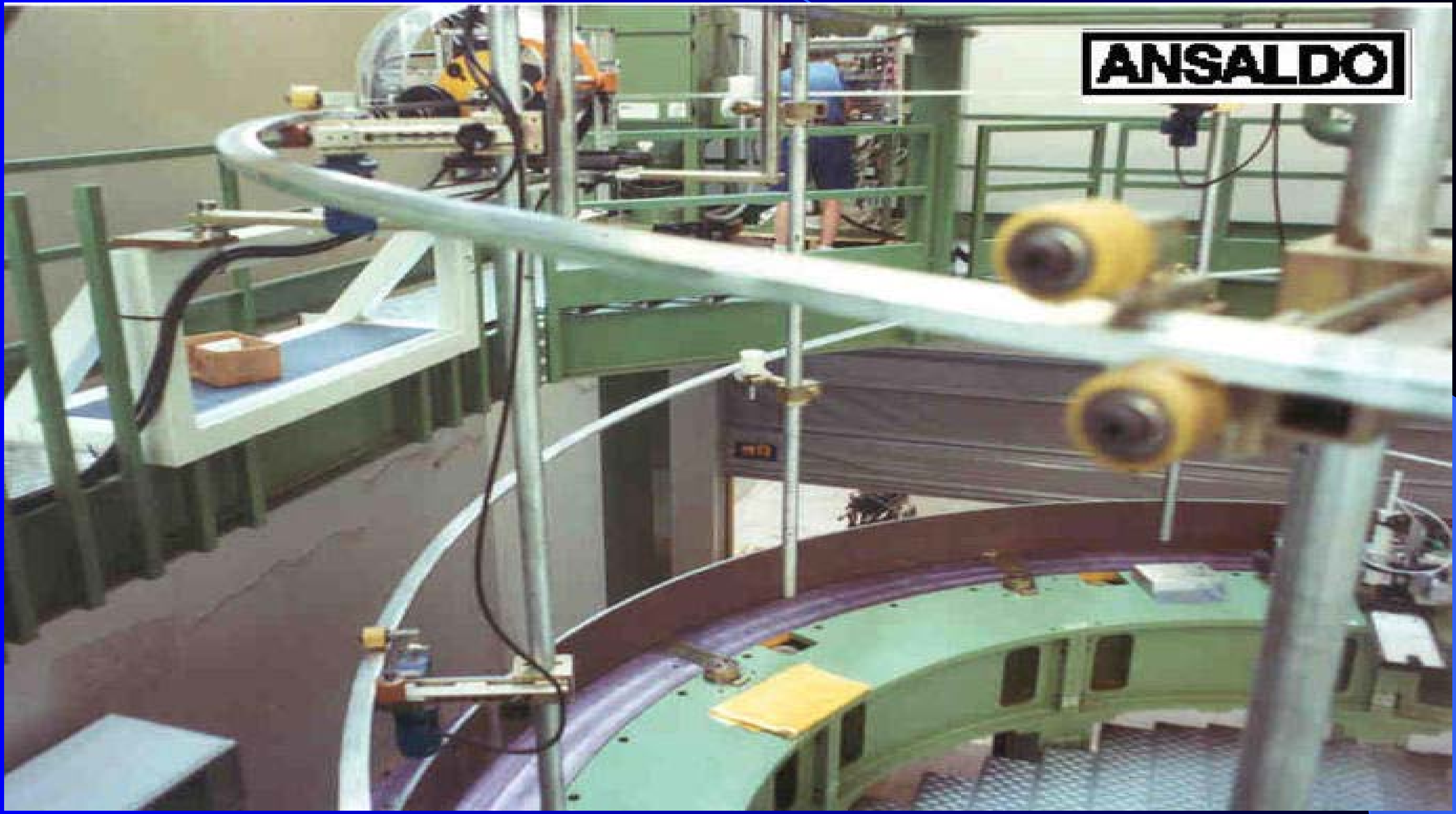


Countries involved: Finland, Japan, Switzerland, France, …

The Winding Machine at Ansaldo (Italy)

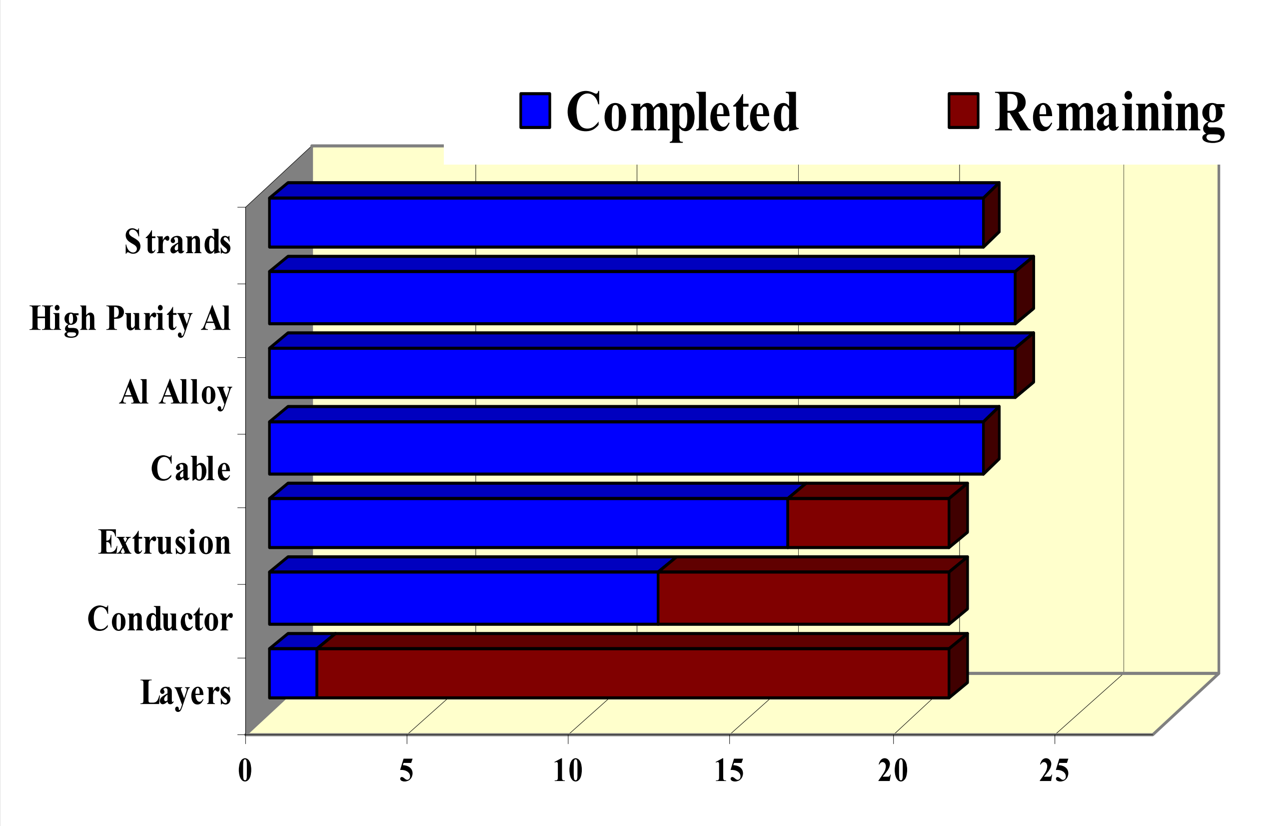


Insertion of Conductor to Winding Drums



Winding of CMS Conductor

Status of Coil Manufacture



- All material delivered
- 100% cabled
- 72% extruded
- 57% EB welded
- Winding started

Industrial Challenges for the CMS Magnet Construction

- Drilling machine for high precision 160 mm x 1 m deep holes
- Continuous co-extrusion of insert (high reliability)
- High current density SC strands 3140 A/mm^2
- Production of aluminium alloy AA 6082 with continuous mechanical properties
- Hot rolling milled flanges of AA 5083 100 mm H321
- Production of 420 mm thick forged blocks for the Yoke
- Winding machine with strong packing pressure but no risk of destroying the insulation
- 9 m titanium tie rods at operating temperature of 4.2 K
- Bending machine to get the conductor out of the vacuum tank
- High precision photogrammetry
- …

The CMS Magnet Project has promoted in many ways the exchange of technology and know-how between Laboratories, Institutes and Industry

Conclusions on the CMS Magnet

- The construction of the CMS Magnet is well advanced and within schedule.

- The CMS Magnet project has benefited tremendously in working closely with dedicated and qualified companies.

- 85 % of contracts awarded and within budget.

- Schedule:
  - Completion 2004
  - Surface test 2005
  - Re-assembly 2006
  - Physics run 2007